Claims

What is claimed is:

1. A method for real-time digital spectral analysis of wide-band signals comprising the steps of:

receiving a wide-band signal;

shifting the center frequency of the wide-band signal by a small fraction ε of its bandwidth;

sampling and digitizing the wide-band signal;

processing the digitized wide-band signal using a digital filter; and,

decimating the digitally filtered wide-band signal.

2. A method for real-time digital spectral analysis of wide-band signals comprising the steps of:

receiving a wide-band signal;

shifting the center frequency of the wide-band signal by a small fraction ε of its bandwidth;

sampling and digitizing the wide-band signal;

de-multiplexing the digitized wide-band signal into N parallel sample streams;

processing the N parallel sample streams in parallel using N digital FIR filters; and,

determining $2^k \cdot N; k = 0,1,...$ sub-band signals by decimating the sample stream from each digital FIR filter by a factor of $2^k \cdot N; k = 0,1,...$, wherein only every $2^k \cdot N^{th}; k = 0,1,...$ sample is retained and the others are discarded.

3. A method for real-time digital spectral analysis of wide-band signals as defined in claim 2, wherein the wide-band signal is sampled at a sample rate of at least twice the bandwidth of the wide-band signal.

4. A method for real-time digital spectral analysis of wide-band signals as defined in claim 2, wherein each of the N digital FIR filters has a different tap-weight.

5. A method for real-time digital spectral analysis of wide-band signals as defined in claim 4, wherein each digital FIR filter is a cosine symmetric digital FIR filter having a linear phase.

6. A method for real-time digital spectral analysis of wide-band signals as defined in claim 5, wherein the bandwidth of each digital FIR filter is approximately $1/N$ of the bandwidth of the wide-band signal.

7. A method for real-time digital spectral analysis of wide-band signals as defined in claim 2, comprising the step of re-quantization by re-scaling and truncating the $2^k \cdot N; k = 0,1,...$ sub-band signals in order to reduce downstream processing load.

8. A method for real-time digital spectral analysis of wide-band signals as defined in claim 2, comprising the step of phase rotating the $2^k \cdot N; k = 0,1,...$ sub-band signals by phase ε using a digital phase rotator producing a de-rotated sub-band signal.

9. A method for cross-correlating de-rotated sub-band signals sub-band by sub-band, the method comprising the steps of:

receiving $2^k \cdot N; k = 0,1,...$ pairs of first and second de-rotated sub-band signals at $2^k \cdot N; k = 0,1,...$ cross-correlators, wherein each pair is received at a different cross-correlator of the $2^k \cdot N; k = 0,1,...$ cross-correlators;

delaying one of the first and second de-rotated sub-band signals with respect to the other in a series of delay intervals at each of the $2^k \cdot N; k = 0,1,...$ cross-correlators;

forming the product of the first and the second de-rotated sub-band signals at each of the delay intervals at each of the $2^k \cdot N; k = 0,1,...$ cross-correlators;

producing a sub-band cross-correlation result at each of the $2^k \cdot N; k = 0,1,...$ cross-correlators by summing the products over a period of time;

transforming each sub-band cross-correlation result at each of the $2^k \cdot N; k = 0,1,...$ cross-correlators by means of a Fourier Transform into a cross-spectrum result; and,

correcting each cross-power spectral point of each sub-band cross-spectrum result with a sub-band scaling term, a gain differential compensation term, a bandshape correction term and a wide-band power gain term.

10. A method for cross-correlation de-rotated sub-band signals sub-band by sub-band as defined in claim 9, comprising digital sub-sample delay interpolation of the de-rotated sub-band signals.

11. A method for cross-correlating de-rotated sub-band signals sub-band by sub-band as defined in claim 9, wherein the delay intervals are equivalent to one sample-interval of a sub-band signal.

12. A method for cross-correlating de-rotated sub-band signals sub-band by sub-band as defined in claim 9, wherein the Fourier Transform is performed after each period of time of summing the products.

13. A method for cross-correlating de-rotated sub-band signals sub-band by sub-band as defined in claim 9, comprising the step of band flattening each of the $2^k \cdot N; k = 0,1,...$ sub-band cross-spectra.

14. A method for cross-correlating de-rotated sub-band signals sub-band by sub-band as defined in claim 9, comprising the step of scaling each of the $2^k \cdot N; k = 0,1,...$ sub-band cross-spectra by a cross spectrum weighting function.

15. A method for cross-correlating de-rotated sub-band signals sub-band by sub-band as defined in claim 9, comprising the step of concatenating the $2^k \cdot N; k = 0,1,...$ sub-band cross-spectra to obtain a wide-band spectrum.

16. A method for cross-correlating de-rotated sub-band signals sub-band by sub-band, the method comprising the steps of:

receiving $2^k \cdot N; k = 0,1,...$ pairs of first and second de-rotated sub-band signals at $2^k \cdot N; k = 0,1,...$ cross-correlators, wherein each pair is received at a different cross-correlator of the $2^k \cdot N; k = 0,1,...$ cross-correlators;

transforming each pair of first and second de-rotated sub-band signals at each of the $2^k \cdot N; k = 0,1,...$ cross-correlators by means of a Fourier Transform into frequency domain;

complex cross-multiplying the Fourier transformed first and second de-rotated sub-band signals at each of the $2^k \cdot N; k = 0,1,...$ cross-correlators; and,

time-averaging the cross-multiplied first and second de-rotated sub-band signals.

17. A method for real-time digital spectral analysis of wide-band signals comprising the steps of:

receiving a first and a second wide-band signal;

shifting the center frequency of each of the first and the second wide-band signal by a small fraction ε_1 and ε_2, respectively, of its bandwidth;

sampling and digitizing the first and the second wide-band signal;

de-multiplexing each of the digitized first and second wide-band signals into first N parallel sample streams and second N parallel sample streams;

processing each of the first and the second N parallel sample streams in parallel using $2 \cdot N$ digital FIR filters;

determining first and second N sub-band signals by decimating the sample stream from each digital FIR filter by a factor of N, wherein only every N^{th} sample is retained and the others are discarded;

re-quantizating the N sub-band signals by re-scaling and truncating in order to reduce downstream processing load;

phase rotating each of the first and second N sub-band signals by phase ε_1 and ε_2, respectively, using a digital phase rotator producing first and second N de-rotated sub-band signals;

receiving pairs of the first and second N de-rotated sub-band signals at N cross-correlators, wherein each pair is received at a different cross-correlator of the N cross-correlators;

delaying one of the first and second de-rotated sub-band signals with respect to the other in a series of delay intervals at each of the N cross-correlators;

forming the product of the first and the second de-rotated sub-band signals at each of the delay intervals at each of the N cross-correlators;

producing a sub-band cross-correlation result at each of the N cross-correlators by summing the products over a period of time;

transforming each sub-band cross-correlation result at each of the N cross-correlators by means of a Fourier Transform into a cross-spectrum result;

correcting each cross-power spectral point of each sub-band cross-spectrum result with a sub-band scaling term, a gain differential compensation term, a bandshape correction term and a wide-band power gain term; and,

concatenating the N sub-band cross-spectra to obtain a wide-band spectrum.

18. A method for real-time digital spectral analysis of wide-band signals as defined in claim 17, wherein the frequency shifts ε_1 and ε_2 are arbitrary.

19. A method for real-time digital spectral analysis of wide-band signals as defined in claim 18, wherein the frequency shifts ε_1 and ε_2 are varied in a quasi-random way during a period of time of summing the products.

20. A method for real-time digital spectral analysis of wide-band signals as defined in claim 17, wherein the first and the second wide-band signal are a same wide-band signal.

21. A method for real-time digital spectral analysis of wide-band signals of a phased array system comprising the steps of:

receiving M wide-band signals from the phased array system;

shifting the center frequency of each of the M wide-band signals by a small fraction $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_m$, respectively, of its bandwidth;

sampling and digitizing the M wide-band signals;

de-multiplexing each of the digitized M wide-band signals into $M \cdot N$ parallel sample streams;

processing each of the $M \cdot N$ parallel sample streams in parallel using $M \cdot N$ digital FIR filters;

determining $M \cdot N$ sub-band signals by decimating the sample stream from each digital FIR filter by a factor of N, wherein only every N^{th} sample is retained and the others are discarded;

re-quantizing the $M \cdot N$ sub-band signals by re-scaling and truncating;

complex mixing each of the $M \cdot N$ re-quantized sub-band signals;

90^0 phase shifting one of two components of each of the complex mixed $M \cdot N$ sub-band signals; and,

forming multiple beams by adding same sub-band components of the $M \cdot N$ sub-bands, the same sub-band components being provided by same digital FIR filters.

22. A method for real-time digital spectral analysis of wide-band signals as defined in claim 21, comprising digital sub-sample delay interpolation of the digitized M wide-band signals.

23. A system for real-time digital spectral analysis of wide-band signals comprising:

a port for receiving a wide-band signal;

a frequency shifter for shifting the center frequency of the wide-band signal by a small fraction ε of its bandwidth;

an A/D converter for sampling and digitizing the wide-band signal;

a de-multiplexer for de-multiplexing the digitized wide-band signal into N parallel sample streams; and,

N processors, each processor for processing one of the N parallel sample streams by digitally FIR filtering and decimating the sample stream in order to determine a sub-band signal.

24. A system for real-time digital spectral analysis of wide-band signals as defined in claim 23, wherein the frequency shifter the center frequency comprise an analog mixer and a local oscillator.

25. A system for real-time digital spectral analysis of wide-band signals as defined in claim 23, wherein the frequency shifter the center frequency comprise a digital single-sideband mixer.

26. A system for real-time digital spectral analysis of wide-band signals as defined in claim 23, wherein each of the N processors re-quantizes the sub-band signal.

27. A system for real-time digital spectral analysis of wide-band signals as defined in claim 23, wherein each of the N processors digitally phase rotates the sub-band signal by phase-rate ε.

28. A system for real-time digital spectral analysis of wide-band signals as defined in claim 27, wherein each of the N processors digitally cross-correlates the sub-band signal with a respective second sub-band signal.